Reputation-based Network Selection Solution in Heterogeneous Wireless Network Environments

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Abstract

The significant developments in terms of both mobile computing device (e.g., smartphones, tablets, laptops, etc.) and the wireless communication technologies (e.g., LTE, LTE-Advanced, WiMAX, etc.), lead towards a converged heterogeneous wireless environment. In this context, the user will be facing the problem of selecting from a number of Radio Access Networks that differ in technology, coverage, pricing scheme, bandwidth, latency, etc. In order to provide high quality of service (QoS) to the user in this heterogeneous wireless environment, a network selection solution is required that will efficiently facilitate the vertical handover between different wireless access networks in a seamless manner. In this paper, we propose a reputation-based network selection solution which aims to select the best value network for the user. We propose a network profiling algorithm that used to compute the reputation of each of the available networks based on the joint collaboration of the users within the network. The network with the best reputation value is recommended for selection and handover.

Keywords: Reputation Mechanism, Heterogeneous Wireless Network, Network Selection, vertical handover

1 Introduction

Due to the rapid evolution of cellular and wireless networks together with the advances in technologies and the rapid adoption of mobile computing devices led towards a multi-technology multi-terminal multi-application multi-user heterogeneous wireless environment representing the next generation of wireless networks. In this context the "Always best Connected" vision emphasis the scenario of variety of radio access technologies that work together in order to provide global wireless infrastructure in which the en-users will benefit from an optimum service delivery via the most suitable available wireless network that satisfies their interests. However, supporting such a connectivity goal is very difficult, mostly due to system complexity and diversity of technologies.

In terms of wireless technologies, wireless networks are grouped into three major categories: Wireless Local Area networks (WLAN), Wireless Wide Area networks (WWAN) and Wireless Personal Area Networks (WPAN). WLAN networks are mostly represented by the IEEE 802.11 family (i.e. including the well-known 802.11a/g/b/n and the recent IEEE 802.11ac) and they offer high data delivery rates, but they have limited transmission range. WWAN networks provide coverage over extremely large areas, best known for their Global System for Mobile Communications (GSM) and Universal Mobile Telecommunications System (UMTS) technologies, the latest Long-Term-Evolution (LTE) protocol provides support for higher data rates which could reach 3 Gbps downlink and 1.5 Gbps uplink [1]. WPAN networks are the smallest wireless networks used to connect various peripheral devices centered around an individual person's workspace. The two kinds of wireless technologies used for WPAN are Bluetooth and Infrared Data Association.

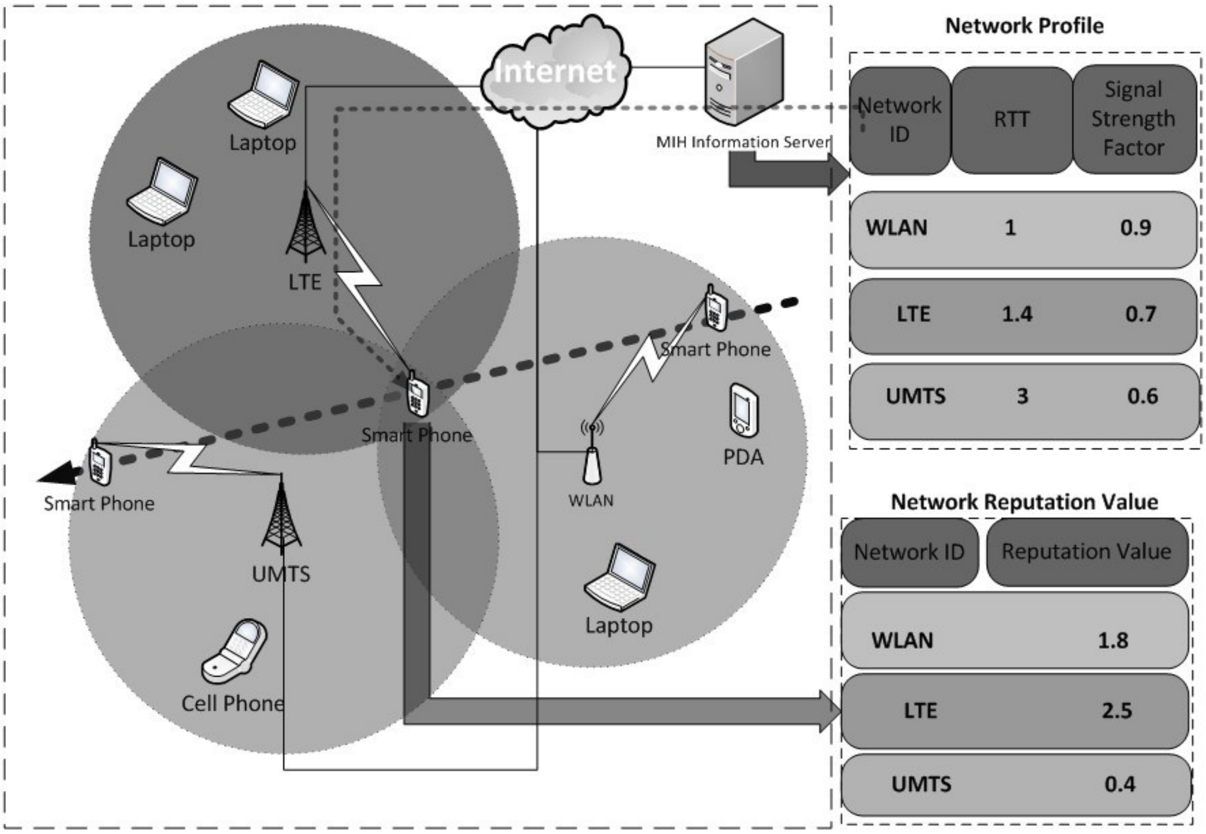

Figure 1. Heterogeneous Wireless Networks Scenario & Information Server Sample

The "optimally connected anywhere, anytime" vision was introduced by ITU in Recommendation ITU-R M.1645 [2] in June 2003 and relies on different radio access networks connected via flexible core networks. The aim is to provide seamless, transparent and QoS-enabled connectivity to the user by taking into account the limitations of the underlying wireless access technology and user preferences.

Moreover, the IEEE 802.21 Media Independent Handover (MIH) Working Group [3] (Jan 2009) considers the interoperability aspects between heterogeneous networks, and has developed a standard referred to as IEEE 802.21. This standard enables the optimization of handover between heterogeneous IEEE 802 networks and facilitates handover between IEEE 802 networks and cellular networks by providing a media-independent framework and associated services. However, the new standard does not provide a network selection mechanism itself.

In this context, this paper proposes a novel Reputation-based Network Selection Solution (RNS) to enable the best selection of a candidate wireless network. RNS is based on the joint collaboration of the users within a network and makes use of the IEEE 802.21 MIH standard mechanisms in order to gather performance information about the current wireless network from the users. This performance information is then aggregated and disseminated to other mobile users in the form of a network profile. The network profile is used to make an informed quality-oriented decision when selecting the candidate network for handover in the heterogeneous wireless network environment.

For example, Fig.1 illustrates a scenario of a mobile user roaming through a heterogeneous wireless environment. In this particular case, there are three different access network technologies considered: WLAN, UMTS and LTE. For each of the networks, network profile stored in the MIH information server. A mobile user (MU) using a smartphone device can be located within the coverage area of a WLAN. Following user mobility, MU can face the choice of selecting between three wireless networks. In this context, the MU can send a request to the MIH Information Server which responds with the network profile of the available networks. Based on the response information, MU can generate the reputation value of each network and make a network selection, then will handover to the new network. The network profile for each network is stored in the MIH information server. In Fig.1, those values are pseudo value for numerical analysis, also shows in Table 1.

The remaining of this paper is organized as follows: Section II discusses related works. In Section III, detailed information about the RNS system architecture and the RNS algorithm are described and discussed. Section IV provides the performances results, and, finally, Section V presents the conclusions and future work directions.

2 Related Work

Reputation systems have been studied and deployed to the wireless environment [4], especially in mobile ad-hoc networks, wireless mesh networks, and Internet-based peer-to-peer, being useful in cooperation scenarios and decision making problems. For example, reputation systems are used in order to help peers decide with whom to cooperate or not. Peers with good reputation are favored.

In [5] an enhanced MIH Information Server to accelerate vertical handover procedures in the 802.21 framework is proposed. They reduce the vertical handover latency by eliminating time-consuming channel scanning procedure. Authors in [6] proposed an energy-aware utility-based user-centric network selection strategy in heterogeneous wireless network environments, which is using the Media Independent Handover Function (MIHF) to gather and exchange information. In [7] an enhanced IEEE 802.21 MIH based framework that integrates a Vertical Handover Management Engine (VHME) for vertical handover decision-making based on networks reputation is described. The authors make use of a large set of parameters that map the QoS and QoE to a network reputation value.

Some other papers [8-10] describe reputation-based network selection strategies and vertical handover solutions. In [8], the authors present a reputation based VHO decision rating system by proposing the use of the grey model first order one variable (GM(1,1)). Their proposed solution provides a quick and efficient prediction of reputation score for a target network in the handover decision making progress. The QoS parameters like Bit Error Rate (BER), delay, jitter and bandwidth are used to calculate the reputation value for UMTS, WiMAX and WLAN networks. The proposed solution was evaluated through simulations using the network simulator NS2. The results show that the reputation-based system can provide the mobile node with advance time to make a successful handover and thus experience an overall higher QoS. Zekri et al in [9] propose a VHO management solution combining the use of reputation as a Quality of Experience (QoE) indicator for fast decision-making. This solution collects individual user experience. By users expressing their past experiences, the system aggregated those individual score to give a reputation value for Wi-Fi, WiMAX and UMTS networks. The performance results show that this solution provides better handover latency and throughput than other solutions. Trestian et al. in [10] propose a reputation-based network selection mechanism using game theory. The user-network interaction is modeled as a repeated cooperative game and the reputation of the network is computed based on the user's payoff. The proposed solution is based on individual user experience and the mechanism is integrated into an extended version of the IEEE 802.21 model.

In all these previous related works, multi-user involvement in information gathering or network reputation building and reputation information exchange has not been considered. These are the main contributions of this paper.

3 Architecture

3.1 System architecture

The RNS block-level architecture is shown in Fig. 2. This system architecture consists of two main components: Mobile Nodes (MN) and a MIH Information Server.

In order to perform network selection, the MN needs the list of candidate networks and also their associated quality levels. 802.21 MIH provides a mechanism to support gathering and exchanging of information between various network components, MIH Information Server and MN. Each of the

MIH-enabled entities contains a cross-layer MIHF. This function provides Service Abstraction Points (SAP) acting as an abstract interface between a service provider and a user entity. The higher-layer user entities employ the MIH-SAP to control or monitor the link-layer entity, and the MIHF uses the MIH-LINK-SAP as an interface together with the link layer to translate the data received from the MIH-SAP. The remote MIHF entities use the MIH-NET-SAP to exchange the information with the MIHF.

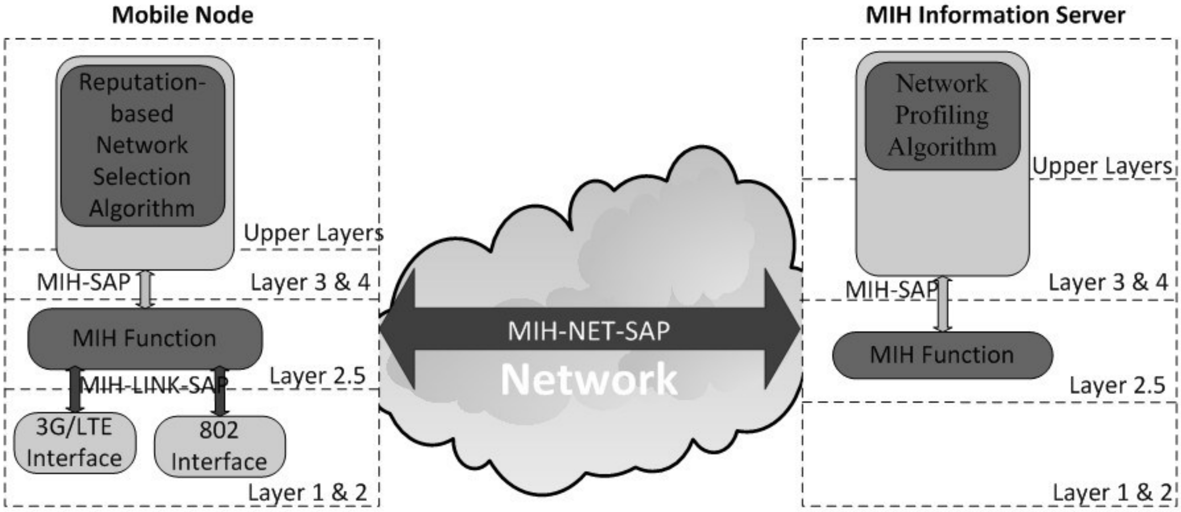

Figure 2. System Architecture

The proposed RNS solution is distributed and consists of a server side component and a client side component. At the server side, the Network Profiling Algorithm (NPA) is based on the joint collaboration of the users within a network. The MIH Information Server gathers the performance information feedback from multiple users within the network and computes the performance factor for that particular network. At the client side, Reputation-based Network Selection Algorithm (RNSA) using the network profile gathered from MIH Information Server computes the network reputation value. The network with the highest reputation value is selected as the target network and the handover process is triggered.

3.2 Network Profiling Algorithm (Server Side)

In order to execute the Network Profiling Algorithm (NPA), the data required includes: current access point (AP) location (X_{ap}, Y_{ap}), MN location (X_{mn}, Y_{mn}), and signal strength of current network i measured at user's current location $Su^i_{(Xmn,Ymn)}$.

For a wireless channel model, the theoretical value of the signal strength of current network i at user's location $St^i_{(Xmn,Ymn)}$ is calculated based on distance d between AP and MN under COST-231 Hata model[11] by using the signal strength equation described in [5][11][12] and in equation (1):

$$PL(d)_{dB} = 46.3 + 33.9\log_{10}(f) - 13.82\log_{10}(h_b) - a(h_r) + (44.9 - 6.55\log_{10}(h_b))\log_{10}(d) + c_m \quad (1)$$

In equation (1), $PL(d)_{dB}$ is the path loss expressed in dB, f is the carrier frequency, h_b is the antenna height at the AP, and d is the distance between the AP and MN:

$$\mathrm{d} = \sqrt{\left(X_{mn} - X_{ap}\right)^2 + \left(Y_{mn} - Y_{ap}\right)^2} \quad (2)$$

$a(h_r)$ is the MN's antenna height correction factor and h_r is the MN's antenna height. The parameter c_m is a constant with values *3 dB* and *0 dB* for urban and suburban environments, respectively. By using equation (3), the theoretical value of the signal strength of user's location $St^i_{(Xmn,Ymn)}$ could be obtained [5]:

$$\mathrm{St}^{i}_{(X_{mn},Y_{mn})} = P_{tdB} - PL(d)_{dB} \quad (3)$$

Where P_{tdB} is the transmit power expressed in dB.

Finally, the signal strength utility value U^{i}_{SS} for the user in current network i at position (X_{mn}, Y_{mn}) is computed using $Su^{i}_{(Xmn,Ymn)}$, $St^{i}_{(Xmn,Ymn)}$ and equation (4).

$$\mathrm{U}^{i}_{SS} = \begin{cases} 1 & ,\mathrm{Su}^{i}_{(X_{mn},Y_{mn})} \geq \mathrm{St}^{i}_{(X_{mn},Y_{mn})} \\ \frac{\mathrm{Su}^{i}_{(X_{mn},Y_{mn})}}{\mathrm{St}^{i}_{(X_{mn},Y_{mn})}} & ,\mathrm{Su}^{i}_{(X_{mn},Y_{mn})} < \mathrm{St}^{i}_{(X_{mn},Y_{mn})} \\ 0 & ,Otherwise \end{cases} \quad (4)$$

The user regularly sends performance reports (UPR) which can be described as multi-tuple as in equation (5):

$$\mathrm{UPR} = [\mathrm{MNID}, (X_{mn}, \mathrm{Y}_{mn}), \mathrm{U}^{i}_{ss}, \mathrm{NetworkID}, \mathrm{RTT}] (5)$$

Where *MNID* is the ID that identifies the mobile node and *NetworkID* identifies the current network. RTT is the Round-Trip Time between the times t_1 which MN sends the report and the time t_2 which MN receives the response from MIH information server:

$$\mathrm{RTT} = t_2 - t_1 \quad (6)$$

NPA is presented in pseudo code in Algorithm below. It describes how the signal strength factor F^{i}_{SS} and average RTT $\overline{RTT_i}$ for each network i can be generated given the utility function value U^{i}_{SS} and RTT received from any reporting node located in that network. NRR_i is the number of performance reports for network i received so far.

Algorithm 1: Network Profiling Algorithm

If (first report) then
  Initialize $NRR_i=0$
if $(NRR_i = 0)$ then
 $F^{i}_{SS} = \mathrm{U}^{i}_{SS}$; $\overline{\mathrm{RTT}}_i = \mathrm{RTT}$;
else
$\mathrm{F}^{i}_{SS} = \frac{\mathrm{F}^{i}_{SS} * \mathrm{NRR}_i + \mathrm{U}^{i}_{SS}}{\mathrm{NRR}_i + 1}$;$\overline{\mathrm{RTT}}_i = \frac{\overline{\mathrm{RTT}}_i * \mathrm{NRR}_i + \mathrm{RTT}}{\mathrm{NRR}_i + 1}$;
end if
NRR_i++;

3.3 Reputation-based Network Selection Algorithm (Client Side)

The RNSA is located at the MN and it based on the network profile report (NPR) sent by the MIH Information Server.

$$\mathrm{NPR} = (\mathrm{NetworkID}, \mathrm{F}^{i}_{SS}, \overline{\mathrm{RTT}}_i, \mathrm{NRR}_i) \quad (7)$$

The reputation value $R_i(X_{mn}, Y_{mn})$ for network i at user's current location (X_{mn}, Y_{mn}) can be calculated as in equation (8):

$$R_i^{(X_{mn},\mathrm{Y}_{mn})} = \frac{F^{i}_{SS} \times \mathrm{Su}^{i}_{(X_{mn},Y_{mn})}}{\overline{RTT}_i} \quad (8)$$

RNSA is presented in pseudo code in algorithm below. Once MN receives the response which consist the NPR, the RNSA algorithm is executing to generate the reputation value of available networks. By comparing the reputation value of available networks $R_i^{(X_{mn},\mathrm{Y}_{mn})}$ and the current network $R_c^{(X_{mn},\mathrm{Y}_{mn})}$, MN selects the highest one as the target network to execute the handover. After this, MN will send a new UPR to MIH information server to update the network profiles that make the reputation mechanism accurate.

Algorithm 2: Reputation-based Network Selection Algorithm

Initial: receives the response from MIH information server, $\mathrm{RTT} = t_2 - t_1$;
if $(\overline{\mathrm{RTT}}_i = 0)$ then
$\overline{\mathrm{RTT}}_i = RTT$;
else
$\overline{\mathrm{RTT}}_i = \frac{\overline{\mathrm{RTT}}_i * \mathrm{NRR}_i + \mathrm{RTT}}{\mathrm{NRR}_i + 1}$;
end if
$R_i^{(X_{mn},Y_{mn})} = \frac{F_{SS}^i \times \mathrm{Su}^i_{(X_{mn},Y_{mn})}}{\overline{RTT}_i}$;
If$(\exists(R_i^{(X_{mn},Y_{mn})} > R_C^{(X_{mn},Y_{mn})}))$ then
Select the highest one as the target network to execute the handover.
else
Send new UPR to MIH information server.

3.4 Network selection and handover

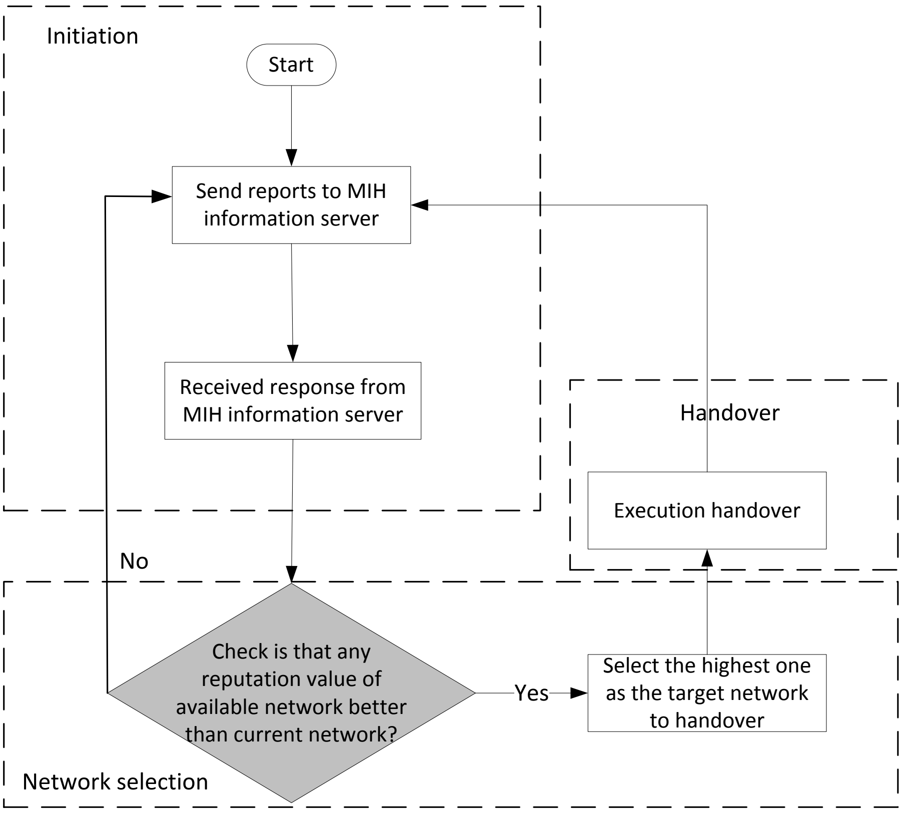

Figure 3. Network Selection and Handover Mechanism

The proposed solution consists of three main phases: Initiation, Network Selection and Handover Execution as depicted in Fig.3. MN sends an information request and user report to the current serving attachment point when it initiates a connection with the current serving network. The current serving network forwards this information request to the MIH information server. The MIH Information Server receives information requests, and user reports from MNs using MIH-NET-SAP. On receiving any information, MIH Information Server sends it from MIHF to the upper-layers in charge with network selection-related data storage and processing, and immediately responds to MN. The information response extends the 802.21 MIH protocol with one additional field: Network Profile Report. This report contains the list of the candidate networks along with signal strength factor, average RTT and NRR. Based on the network profile report, the MN generates the reputation value for each of the candidate networks. The candidate network with the highest reputation value is selected as the target network. Finally, MN executes handover from current network to target network. Once MN success handover to the target network, MN will send a new UPR to MIH information server contains the RTT value of the previous network and signal strength utility factor of the new network.

4 Numerical Analysis

Table 1. Network Profile for Each Network

	$\overline{\mathrm{RTT}}_i$	F^i_{SS}
UMTS	3	0.6
LTE	1.4	0.7
WLAN	1	0.9

This section describes the simulation scenario and the numerical results and analysis. This scenario considers the case of a typical day in a business professional life which travels from point A (e.g., home) to point E (e.g., office) as illustrated in Fig 4. The mobile user will pass through three different networks: UMTS, LTE and WLAN. On the way to the office the mobile user needs to be always connected to the internet. Thus, the RNSA is enabled in the user's mobile device and the MN will select the best network to handover to in order to support "always best connect" internet service. The values in Table 1 are pseudo value for each network for numerical analysis, and Table 2 is also using the pseudo signal strength level instead of real data. Based on the data provided in Table 1 and Table 2, and by using the equation (8) the reputation values for each network are listed in Table 3.

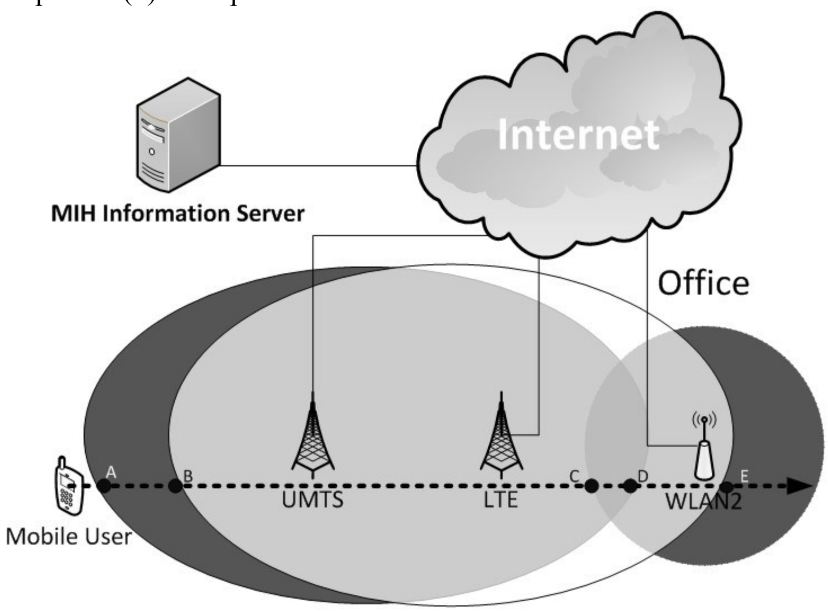

Figure 4. Simulated Scenario

Table 2. Signal Strength level for Each Network

	A	**B**	**C**	**D**	**E**
UMTS	1	**3**	2	1	-
LTE	-	2	**5**	**4**	2
WLAN	-	-	2	**4**	**5**

Table 3. Reputation Value of Each Network

	A	**B**	**C**	**D**	**E**
UMTS	**0.2**	0.6	0.4	0.2	-
LTE	-	**1**	**2.5**	2	1
WLAN	-	-	1.8	**3.6**	**4.5**

From the Table 3, at point B the MN will handover to LTE network, even if the signal strength level of UMTS is better than LTE at this point, by considering the network reputation based on both signal strength and RTT, the reputation value of LTE is better than the one for UMTS. At point C the MN will not handover to WLAN network until the MN moved to the point D. In point D the signal strength level of both LTE and WLAN are the same, but WLAN has a better reputation factor in both signal strength and RTT. Finally, user reaches the destination at point E.

5 Conclusions and Future Work

This paper proposes a reputation-based network selection solution in heterogeneous wireless network environments. Based on the location of MN, signal strength of MN and the RTT of heterogeneous networks, the proposed solution selects the most appropriate network for the user.

Numerical results show that the proposed algorithm achieves a good reputation value in heterogeneous wireless network environments. And the network selection and handover mechanism will support the "always best connected" paradigm.

Further work will use the network simulator NS3 to evaluate the proposed algorithm under various scenarios. Location information from user reports to estimate user route and therefore future user position relative to various networks' coverage areas will be considered as the next step.

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